# §23. Asymmetrical Normal-Zone Propagation in the Al-Stabilized Superconductor for the LHD Helical Coils

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An aluminum-stabilized superconductor is used for the helical coils of the Large Helical Device (LHD). Dynamic stability is important in this type of superconductors due to slow magnetic diffusion process in pure aluminum. The transport current can be partially transferred to the aluminum stabilizer in normal-to-superconducting (N-S) boundaries and temporal and finite-length normal-zone propagation could be observed. It has been confirmed in the former short-sample tests as well as in small R&D coil tests that the propagation velocity of the generated normal-zone differed in two directions along the superconductor [1]. This difference could be observed only with a situation that the external magnetic field was applied parallel to the wider surface of the conductor so that the current transfer from the superconducting strands to the metal stabilizers occurs in the direction perpendicular to both the transport current and the external magnetic field. It thus indicates that this phenomenon might be caused by some electromagnetic mechanisms.

An R&D coil (inner and outer radii: 200 and 400 mm) was constructed using the same type of superconductor as that used for the LHD helical coils. The R&D coil was tested with liquid helium at temperature 4.4 K as well as at lower temperature (down to 3.5 K) using cryogenic compressors. The stability test was conducted using resistive heaters attached to the surface of the innermost windings and propagation of normal-zones was monitored using potential taps distributed along the conductor. We observed that the propagation velocity was asymmetrical with respect to the two longitudinal directions along the conductor, as was found in the short-sample tests. Moreover, up to a certain coil current, the generated normal-zone propagates only in one direction and it recovers back into the superconducting state from the other end. Thus, the spatial profile of a normal-zone clearly takes a form of that of a so-called "traveling normal-zone" [2].

Since the number of potential taps is restricted, in the 2003 experiment, we have installed 24 pick-up coils in the interior space of the R&D coil to monitor the propagation of normal-zones in a wider region. Figure 1 shows an example of the observed signals of pick-up coils. These signals will have to be compared with the ones obtained by potential taps and the entire process of normal-zone propagations will be examined.

In order to clarify the mechanism for causing the observed asymmetrical normal-zone propagation, the current transferring process from the superconducting strands to the metal stabilizers has been considered. When the current transfer occurs in the direction perpendicular to the external magnetic field, a Hall electric field is generated in the longitudinal direction. In one N-S boundary, the Hall electric field is generated in the opposite direction to the intrinsic electric field applied by the external power supply. Therefore, the effective resistance of the metal stabilizer could be lowered and the characteristic length for current transfer becomes longer due to the lower joule heating power. On the other hand, at the other N-S boundary, the power density is enhanced due to the longitudinal Hall electric field. Figure 2 shows a result of this analysis with a simplified model of the HC conductor. As is seen in Fig. 2, the power generation in two N-S boundaries could be 30 times different, which seems to explain the observed asymmetrical normal-zone propagation.

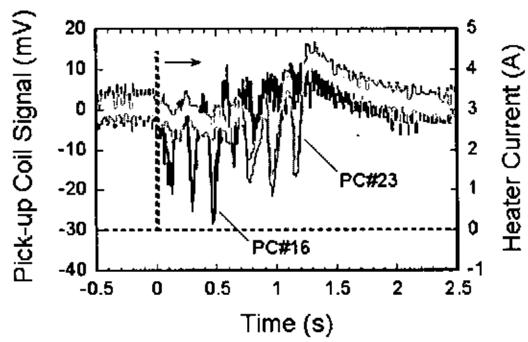


Fig. 1 Pick-up coil signals obtained during normal-zone propagation with a coil current of 11.4 kA.

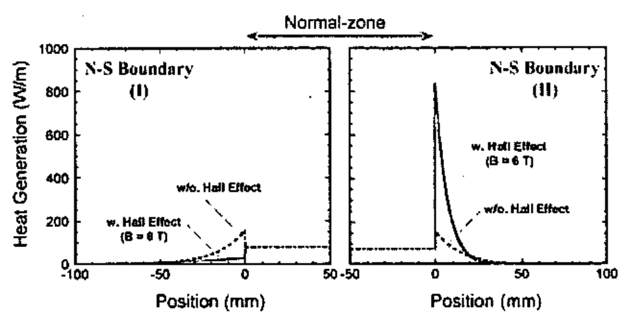


Fig. 2 Heat generation as a function of the position from the NS boundaries.

References

1) N. Yanagi, et al., IEEE Trans. Appl. Supercond. 9 (1999) pp. 1113-1116.
2) N. Yanagi, et al., to be published in IEEE Trans. Appl. Supercond.